EN200

LAB #3 PRELAB

ARCHIMEDES & CENTER of FLOTATION

Instructions:

1. The first part of this lab consists of a prelab that covers the theory the will be examined experimentally in this lab.

2. The prelab is to be completed and handed in to your instructor at the beginning of the lab period.

3. If you can, answer the questions without referring to your notes. Only refer to your notes if you are confused or fail to understand a concept. This will greatly improve your understanding of the concepts this lab is designed to reinforce. Remember you will have no notes during quizzes, tests, and exams.

4. By conscientiously completing this prelab, you will have a thorough understanding of what the lab is trying to show. Your lab performance will be maximized.

5. For full credit, all work must be shown on your lab. This means that you must show generalized equations, substitution of numbers, units, and final answers. Engineering is communication. Work that is neat and shows logical progression is much easier to grade.

Student Information

Name: ____________________________

Section: __________

Date: ____________

Aim

- Reinforce the student's understanding of Archimedes Principle.
- Reinforce the student's concept of static equilibrium.
- Reinforce the student's concept of the center of flotation.

Lab Apparatus

1. In this lab, two simple wooden hull shapes are used as floating bodies (one symmetrical shape and one unsymmetrical shape). Their tops have been inscribed so that half-breadths can be measured and used to determine hull form characteristics. At the bow and stern are draft marks measured from the keel. The tank in which they will float has been fitted with a *weir* and a spillway through which any displaced water will run and be collected for measurement. This opening, in effect, provides a constant water level in the tank. A suitable container for collecting the water, a scale for weighing the hull shape and displaced water, and a ruler for taking measurements are provided.

Archimedes and Static Equilibrium Theory

2. In the first part of the lab, the displacement (weight) of the symmetrical hull will be determined by four different means.

   2.1 It will be weighed on a scale.

   2.2 The volume of water it displaces will be weighed on a scale.

   2.3 Its underwater volume will be calculated and used to calculate buoyant force and displacement.

   2.4 The hydrostatic force supporting the hull will be calculated.

3. Which of the techniques described above will give the most accurate weight?

   ________________________________ Why? ______________________________________

   ____

4. Which of the techniques described above could be applied to a full-sized ship?

   ________________________________ Why? ______________________________________

   ____

5. Archimedes Principle states that:

> *"An object partially or fully submerged in a fluid will experience a resultant vertical force equal in magnitude to the weight of the volume of fluid displaced by the object."*

In EN200 we call this vertical force the "buoyant force" or "force of buoyancy" and it is given the symbol F_B.

6. In the box below, write the mathematical relationship described by Archimedes Principle that links F_B with the submerged volume (∇) of a floating body.

7. For each symbol used in the equation write out its name and give its units.

Symbol	**Name**	**Units**

8. When placing the wooden hulls in the tank of water, if they float (positively buoyant) will they be in static equilibrium?

____

9. What are the two necessary conditions for an object to be in static equilibrium?

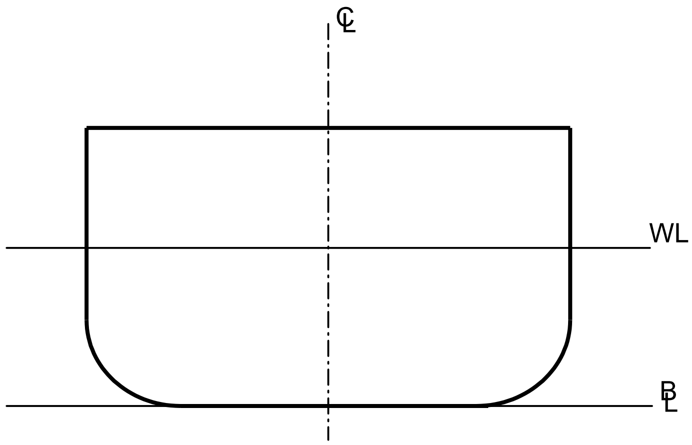
Condition 1: ____

Condition 2: ____

10. Using the conditions for static equilibrium, in the box below, write the mathematical relationship that links the buoyant force (F_B) being experienced by a floating body and its weight or displacement (Δ).

11. Combine the expressions given in (6) and (10) to give the mathematical relationship linking the submerged volume of a floating object (∇) with its displacement (Δ).

12. On the section of a floating hull form below, draw the two force vectors described above, and clearly show and name the centroids through which they act.



13. By filling in the table below, describe how the two centroids displayed above are referenced on a ship.

	Reference Point	Symbol	Name
Vertically			
Transversely			
Longitudinally			

Hydrostatic Pressure Theory

14. In the box below, give the equation used to calculate the hydrostatic pressure below the water's surface.

15. What are the units of pressure used in EN200? ___________________________________

16. Give the equation you would use to calculate the hydrostatic force on an area of A in^2 at a depth h below the water's surface.

17. In Naval Architecture, what is the more common name given to the hydrostatic force being experienced by a ship?

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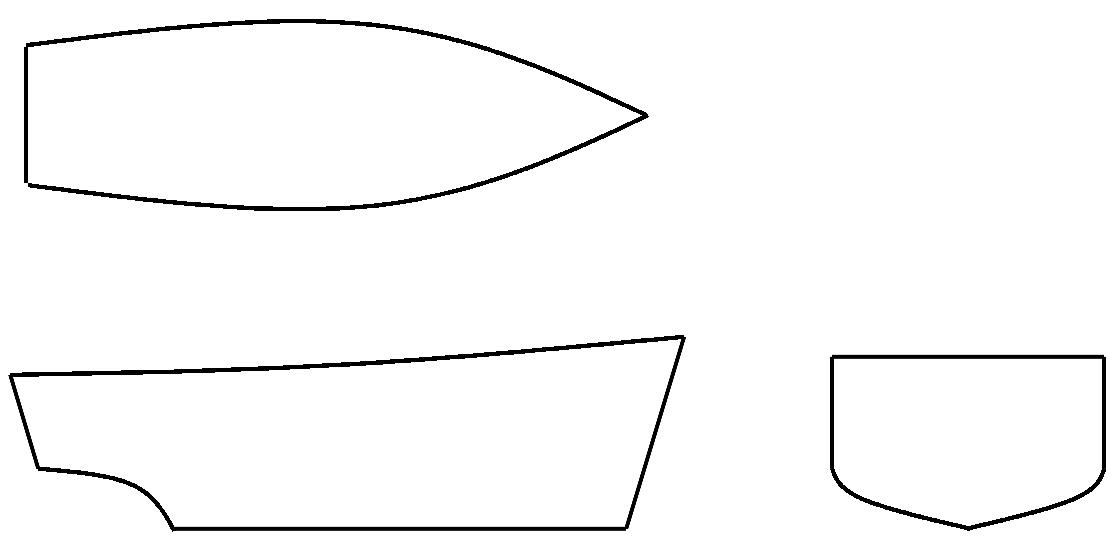
Center of Flotation Theory

18. On the three orthogonal views of a hull form below, draw in the waterline, centerline, midships, and show the center of flotation on each view.



19. What is the relevance of the center of flotation to the ship motions of pitch and roll?

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20. What is the significance of the center of flotation with regard to the waterplane?

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21. Describe parallel sinkage:

____

____

22. Where would a weight have to be placed on a ship to achieve parallel sinkage?

____

23. Complete the table below to describe how the center of flotation is referenced on a ship.

	Reference Point	**Symbol**	**Name Given to Reference Distance**
Transversely			
Longitudinally			

EN200

LAB #3

ARCHIMEDES & CENTER of FLOTATION

Instructions:

1. This lab is conducted in the Hydro Lab on the lab deck of Rickover Hall.

2. Prior to arriving in the Hydro Lab, read through the lab procedure so that you are familiar with the steps necessary to complete the lab.

3. You will need to bring this lab and a calculator the lab period.

4. The lab is to be performed in small groups of 2 or 3. However, each member of the lab group is to submit their own work. You can ask questions and discuss the content of the lab amongst yourselves; the submitted work must be your own.

5. Follow the stages of the lab in consecutive order. The lab follows a logical thought pattern and jumping ahead without completing the intervening theory questions will limit your understanding of the concepts covered.

6. For full credit, all work must be shown on the lab. This means that you must show generalized equations, substitution of numbers, units, and final answers.

7. This lab is to be submitted at the end of the lab period. You should have sufficient time to complete the entire lab.

Student Information:

Name: ________________________________ Date: ___________

1st Partner: _____________________________

2nd Partner: _____________________________

Part 1: Archimedes Principle and Determination of Displacement

1. Weigh the symmetrical model on the scale and record its weight below.

Scale weight of symmetrical model (lb)	

This weight corresponds to the displacement (Δ) of the model. The remainder of Part 1 of the lab verifies this weight using three different techniques.

Displacement Measurement from Weight of Displaced Water

2. Fill the tank to a level just above the height of the weir and let the excess water flow into a bucket. Allow about 5 minutes for the water to stop dripping. Empty the bucket into a sink or drain – **DO NOT DUMP EXCESS WATER INTO THE TOW TANK.** Also ensure the small can is empty.

3. Weigh the empty bucket and record its weight in the table below.

4. Holding the large bucket under the weir, carefully lower the model into the tank making sure you keep the model upright. After the initial rush of water, the remaining dripping water can be caught in the small can.

5. Wait at least 5 minutes for the water to finish dripping over the weir. While you are waiting, complete steps (7) through (14).

6. Pour the water from the small can into the bucket and complete the table below.

Weight of Empty Bucket (lb)	
Weight of Collected Water and Bucket (lb)	
Weight of Displaced Water (lb)	
Magnitude of Buoyant Force, F_B (lb)	
Displacement of Model, Δ (lb)	

7. What principle states that the weight of the collected water will be equal to the buoyant force experienced by the model?

____

8. In the box below, write the mathematical expression associated with this principle.

9. What principle indicates that the magnitude of the buoyant force being experienced by the model is equal to its displacement?

____

10. In the box below, write the two mathematical expressions linking displacement (Δ) with buoyant force (F_B) and then with the weight of the collected water.

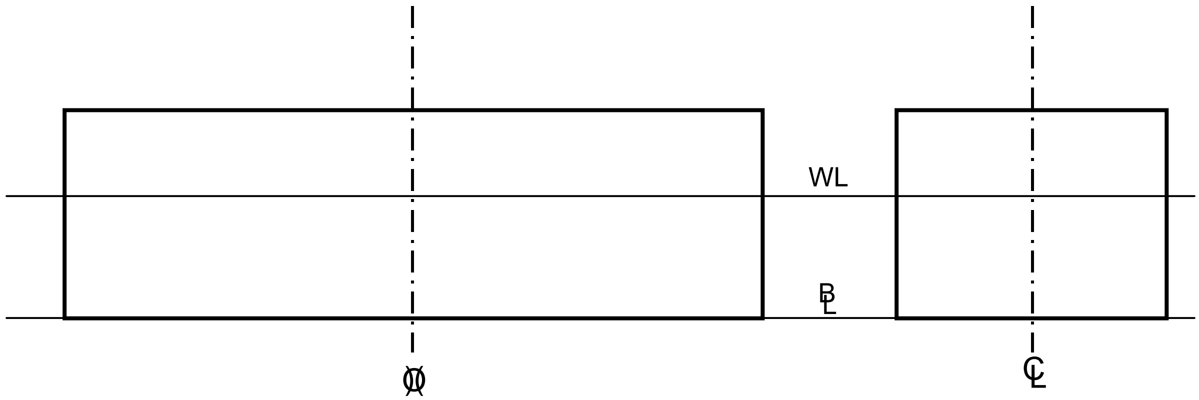
11. The mean draft (T_M) is the average of the forward and aft drafts as measured at their respective perpendiculars. Use this relationship and observations of the floating model to complete the table below.

T_{aft} (inches)	
T_{fwd} (inches)	
T_M (inches)	

12. Using your value for T_M and assuming that the model is of uniform density, estimate the following values that describe the location of the centers of buoyancy (B) and gravity (G) for the floating symmetrical model. Ignore the weight of the handles.

Centroid	**Parameter**	**Value (inches)**
Center of Buoyancy (B)	KB (VCB)	
	TCB	
	LCB	
Center of Gravity (G)	KG	
	TCG	
	LCG	

13. Confirm your understanding of these quantities by plotting the location center of buoyancy (B) and the center of gravity (G) on the shear and body views of the symmetrical model below. Ensure you accurately locate these centroids relative to the waterline.



Displacement Measurement from Submerged Volume Calculation

14. Remove the symmetrical model from the tank and measure the half-breadths at each station along its length. Record the half-breadths in the table below. Station 0 corresponds to the FP, and station 10 corresponds to the AP.

Station	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Half-Breadth (inches)											

15. Determine the station spacing. **Station spacing (*dx*) =** ________________

16. In the space below, calculate the waterplane area of the symmetrical model using Simpson's first rule. For full credit, ensure you include the following steps:

   a. Draw a sketch of the area you are integrating, including the differential element.
   b. Write the general calculus equation.
   c. Write the generalized equation for Simpson's first rule.
   d. Substitute data from steps 15 and 16 into the generalized equation.
   e. Calculate waterplane area and box your answer.

17. In the box below, calculate the submerged volume (∇) of the model using data from steps 11 through 16.

18. Why can't this technique be used to calculate the submerged volume of a normal hull form?

____

19. To calculate the buoyant force from this value of submerged volume, it is necessary to determine the density of the water in the tank. Use the data in enclosure (1) and the temperature of the water in the tank to interpolate its density using the table below.

	Temp (°F)	**ρ (lb-s^2/ft^4)**
Next Lowest Temperature in Data		
Tank Water Temperature		
Next Highest Temperature in Data		

20. Use the values of submerged volume form step (17) and density from step (19) to calculate the symmetrical model's displacement (Δ).

Displacement Measurement from Hydrostatic Force Calculation

21. In the box below, give the generalized equation for hydrostatic pressure and substitute values found in steps (11) and (19) to calculate the hydrostatic pressure at the base of the symmetrical model's hull.

22. Observing the shape of the symmetrical hull, what is the link between the area at the base of the hull and the waterplane area calculated in step (16)?

____

23. Use the pressure calculated in step (21) and your answer to questions (22) to calculate the hydrostatic force acting on the base of the hull.

24. Observing the shape of the symmetrical hull, what is the resultant force hydrostatic force acting on the sides of the model?

____

Why? ____

25. Using your answers to the above questions, write the mathematical equation that links the hydrostatic force with the buoyant force and the model's displacement.

26. What is the model's displacement as determined from its hydrostatic force? ___________

Analysis of Results

27. From the observations and calculations you have made, complete the following table. Calculate the percent error in that table cell.

Technique	Displacement, Δ (lb)	Percent Error	Explanation of Error
Scale Weight of Model		N/A	N/A
Weight of Displaced Water (Step 6)			
Submerged Volume (∇) Calculation (Step 20)			
Hydrostatic Force Calculation (Step 26)			

28. Have these values verified Archimedes Principle and the principle of static equilibrium? Explain your answer.

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Part 2: Longitudinal Center of Flotation

29. Carefully place the non-symmetrical model in the tank and complete the table below.

Unloaded Condition	
T_{aft} (inches)	
T_{fwd} (inches)	
T_M (inches)	
Trim (inches)	

30. By observing the shape of the non-symmetrical model, qualitatively estimate the position of the center of flotation (F). Circle one of the answers below.

A. Forward of midships B. At midships C. Aft of midships

31. Making sure you have a can ready to collect any displaced water; carefully load the model on the centerline at Stations 4 with a 5-pound weight.

32. Record the model's drafts in the table below.

Loaded Condition	
T_{aft} (inches)	
T_{fwd} (inches)	
T_M (inches)	
Trim (inches)	

33. Comparing data from the "Unloaded" and "Loaded" conditions, what change in trim (δTrim) has occurred?

δTrim = ____________________________________

Why has this occurred? ____

____

34. What is the name of the point where the weight would have to be placed on the model in order to achieve zero change in trim (δTrim = 0 inches)?

____

35. By a trial and error basis, move the 5-pound weight so that parallel sinkage is achieved. When you are satisfied, complete the following table.

Loaded for δTrim = 0 Condition	
T_{aft} (inches)	
T_{fwd} (inches)	
T_M (inches)	
Trim (inches)	

36. Measure the location of the 5-pound weight to determine a value for the longitudinal center of flotation of the non-symmetrical hull.

LCF = ___________________________________

37. Using the data you collected in steps (29) and (35), calculate the Pounds Per Inch Immersion (PPI) of the non-symmetrical model.

38. In the box below, calculate the trimming moment associated with moving the 5-pound weight from its initial location to the center of flotation. Remember, a moment is a force (w) times a distance (l).

39. Using the information collected in steps (33), (35), and (38), calculate the model's Moment to Change Trim One Inch (MT1"). Recall that δTrim = (w)(l)/MT1".